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Parviainen, Tuuli

2019-08

Parviainen , T , Lehikoinen , A , Kuikka , S & Haapasaari , P 2019 , ' Risk frames and multiple ways of knowing : Coping with ambiguity in oil spill risk governance in the Norwegian Barents Sea ' , Environmental Science & Policy , vol. 98 , pp. 95-111 . https://doi.org/10.1016/j.envsci.201

http://hdl.handle.net/10138/302004
https://doi.org/10.1016/j.envsci.2019.04.009

Environmental Science and Policy 98 (2019) 95–111

Contents lists available at ScienceDirect

Environmental Science and Policy

journal homepage: www.elsevier.com/locate/envsci

Risk frames and multiple ways of knowing: Coping with ambiguity in oil spill risk governance in the Norwegian Barents Sea

Tuuli Parviainen[a,*], Annukka Lehikoinen[b], Sakari Kuikka[a], Päivi Haapasaari[a]

[a] University of Helsinki, Finland, Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, P.O Box 65, Viikinkaari 1, FI-00014 Helsinki Finland

[b] University of Helsinki, Finland, Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, Kotka Maritime Research Center, Keskuskatu 10, FI-48100 Kotka, Finland

ARTICLE INFO

Keywords:
Maritime governance
Oil spills
Offshore petroleum industry
Risk frames
Mental models
Influence diagrams
Knowledge production

ABSTRACT

The opening of new areas for offshore drilling in the Arctic is highly controversial. As ice cover in the region is melting at an alarming rate, new areas have been opened for petroleum industry in the Norwegian Barents Sea. Our qualitative analysis examines risks related to the petroleum operations in the newly opened areas and provides insight into the complex and socially constructed nature of the risks. With the use of visual influence diagram- based mental modelling approach, we demonstrate the multiple ways in which the risks are understood and defined. We also analyse the type of knowledge that the risk frames are based on. The influence diagrams present the risk frames in a clear, visual, form. The study indicates that the existing governance framework fails to treat the ambiguity around oil spill risks: the current risk assessments and risk management do not reflect on the multiple ways in which the participants in this study 1) frame the problem situation, 2) how they identify different measures to manage risks, and 3) what are considered as key knowledge needs and knowledge producers by the participants. We suggest that social learning and collaborative knowledge production are needed to move towards developing shared understanding of the problem situation. Finally, we suggest that the rigorous examination and the unveiling of ambiguity may help developing deliberative risk governance measures and moving towards sustainability transformations.

1. Introduction

Ice cover in the Barents Sea is receding fast due to climate change: the Barents Sea is expected to become the first ice-free Arctic region by around 2050 (AMAP, 2017b). As the ice is retreating, new areas are becoming increasingly accessible for economic activities such as shipping and offshore oil and gas drilling. For the Arctic states, the potential economic gains are alluring. In Norway, new areas have been opened for both oil exploration and exploitation as part of the 23rd and 24th licensing rounds.

The decision to open new areas for maritime operations remains highly controversial. The risks of offshore operations closer to the ice edge are exacerbated due to the possible presence of ice, harsh weather conditions, insufficient infrastructure, and the ineffectiveness of current prevention and response technologies in iced-conditions (AMAP, 2017a; Arctic Council, 2009; Bambulyak et al., 2014; Gulas et al., 2017; Nuka Research and Planning Group, LLC, Pearson Consulting, LLC, 2010; Sydnes and Sydnes, 2011; Wilkinson et al., 2017). Considering the contribution of fossil fuels to climate change, opening new areas for petroleum industry impede reaching the goals of the Paris climate agreement (AMAP, 2017b; CICERO, 2017; ICCP, 2018; McGlade and Ekins, 2014; Petrick et al., 2017).

The complex nature of oil spill risks presents serious challenges in oil spill risk governance. Conventionally, oil spill risks are considered in terms of probabilities and consequences alone (e.g. Goerlandt and Montewka, 2015; Lehikoinen et al., 2015; Spaulding, 2017). Oil spill risks can be considered systemic risks that are characterized by high levels of complexity and surrounded by uncertainty as well as ambiguity i.e. differing, and often conflicting, perceptions of risks, and societal values (Renn, 2008; Renn et al., 2011). Recognizing the subjective and value-laden nature of risks is a necessary part of risk management decisions (Slovic, 2001).

The current regulatory framework for oil spill risks in the Barents Sea comprises different regulatory measures, strict industry standards

* Corresponding author at: Ecosystems and Environment Research Programme, Faculty of Biological and Environmental Sciences, P.O Box 65 (Viikinkaari 1), FI-00014 Helsinki, Finland.

E-mail address: tuuli.parviainen@helsinki.fi (T. Parviainen).

https://doi.org/10.1016/j.envsci.2019.04.009
Received 18 December 2018; Received in revised form 25 March 2019; Accepted 15 April 2019

(e.g. ISO, CEN and NORSOK standards), the ecosystem-based management plan for the Barents Sea, and the comprehensive oil spill response and preparedness system. However, the risk assessments and risk management have largely focused on natural sciences and engineering studies and the management outcomes have failed to reflect the multiple viewpoints and meanings of the diversity of stakeholder concerns as well as the different systems of knowledge and sources of knowledge (Blanchard et al., 2014; Hauge et al., 2014; Knol, 2010a, 2010b).

In the context of high uncertainty and diversity of values, collaborative approaches and the integration of different types of knowledge in risk governance processes is highlighted (Chateauraynaud, 2009; de Marchi, 2015; Failing et al., 2007; Gregory et al., 2006; Jasanoff, 1998, 2003; Klinke and Renn, 2012; Petts, 2004; Renn et al., 2011; Van Der Sluijs et al., 2005). For example, Renn et al. (2011) call for inclusive and integrative risk governance approaches for complex risks. In the same vein, some highlight the need for moving from expert calculations to integrated approaches challenging the idea that we can prevent and restore damage by more advanced technologies alone (De Marchi, 2015). Failing et al. (2007) explore how to integrate both local and scientific knowledge in environmental decision-making with the use of a practical structured decision process. Petts (2004) discusses the barriers to participation and deliberation in risk decisions. Previous research on management of risks of offshore drilling in the Lofoten area, Norway, emphasize that due to the contested nature of risks, it is important to look at the process of how scientific knowledge is constructed and translated to policy context (Knol, 2010a, 2010b) and that there is a need for participatory dialogue, involving all relevant knowledge and value systems, in order to elicit the uncertainties associated with routine petroleum operations (Blanchard et al., 2014).

This study contributes to the discussion by exploring how to cope with ambiguity in oil spill risk governance in the Barents Sea. We use an influence diagram-based mental modelling approach to gain a better understanding of the way risks related to the offshore operations are framed and understood. We define ambiguity as a distinct type of uncertainty that refers to the different ways of understanding, interpreting, and knowing reality (Brugnach et al., 2008). This signifies that ambiguity can't be interpreted in isolation, but only in the socio-technical-environmental context where it is produced in, i.e. within its frame (Brugnach et al., 2008).

The paper is structured as follows. Section 2 introduces the case study and describes the key sources of knowledge in the process towards opening new areas. Section 3 provides the theoretical background to the study and introduces the use of influence diagrams that aid to identify and illustrate the complex nature of oil spill risks. Section 4 presents the results of the study, and in Section 5, the different risk frames as well as the need for collaborative risk governance measures and social learning are discussed. Section 6 is for conclusions.

We posit that paying attention to the various risk frames provides a way of coping with ambiguity in risk governance in the Barents Sea. The study indicates the need for knowledge co-production and social learning processes in risk governance. Finally, we suggest that the rigorous examination and the unveiling of ambiguity may help developing deliberative risk governance measures and moving towards sustainability transformations.

2. Case study

The Barents Sea is a high latitude Arctic shelf sea (AMAP, 2017a). It is one of the most productive oceans in the world: it hosts more than two hundred species of fish as well as diverse communities of plankton, seabirds and mammals (AMAP, 2017a; Eriksen et al., 2017; Jakobsen and Ozhigin, 2011; NMCE 2014). Especially the frontal zones, the polar front (the boundary front between Arctic water and the Atlantic water) and the marginal ice zone (MIZ; the transitional zone between ice-covered sea and the open sea), are highly productive and support plankton booms that provide food supplies for fish, seabirds and marine mammals (AMAP, 2017a; NMCE 2014).

In recent years, the Norwegian government has opened new areas in the Barents Sea for both oil exploration and exploitation. Oil and gas revenues provide a large source of revenue for Norway. Norway is the world's 8th largest exporter for crude oil and crude oil is one of the most important commodities for Norwegian economy (NPD and NMPE, 2018). The Barents Sea is estimated to hold up to 65% of the total undiscovered oil and gas resources on the Norwegian Continental Shelf (NPD, 2017) and to ensure future revenues, Norway is investing in new technologies to reduce the price of drilling as well as expanding oil production further in the North (Knol and Arbo, 2014).

The decision for opening the Barents Sea southeast to petroleum activity was made in 2013 by the Norwegian parliament ("Opening of the Barents Sea Southeast (Meld. St. 36 (2012–2013)" (NMPE, 2013a) and "Supplementary white paper - Opening of the Barents Sea Southeast (Meld. St. 41 (2012–2013)"(NMPE, 2013b). This policy is in line with the Meld. St. 28 "An industry for the future" (NMPE, 2011) report, which outlines the future directions of petroleum industry in Norway and highlights petroleum industry as "a key activity in Norway for decades to come" (NMPE, 2011). The decision followed the Treaty on Maritime Delimitation and Cooperation in the Barents Sea and the Arctic Ocean between Russia and Norway (2011), under which the Barents Sea southeast is recognized as a part of the Norwegian Continental Shelf. An impact assessment under the Petroleum Act was conducted for the Barents Sea southeast in 2012–2013.

New areas are opened as part of licensing rounds under the Petroleum Act that provides the general legal basis for sound resource management[1] . The licences grant petroleum companies the right and duty to carry out exploration drilling, seismic surveys, and other activities. In January 2015, as part of the 23rd licensing round, the Norwegian government opened up 54 blocks in the Barents Sea. These include blocks in further northernly and easterly areas than in the past: eight blocks were situated North of the 74th parallel and another eight along the Russian borderline. In 2016, the Ministry of Petroleum further announced the nomination of blocks for the 24th licensing round on the Norwegian Continental Shelf (Fig. 1). In June 2018, the Ministry of Petroleum and Energy offered further 9 production licenses in the Barents Sea. Three of the new production licenses are in the 74th parallel including a total of six blocks, whereas 27 blocks are located in the 73rd parallel. (NPD, 2018; Staalesen, 2018).

Norway has developed ecosystem-based management plans for its marine areas. The overall framework for oil and gas activities (such as permitted areas, restrictions on when drilling is permitted, and identification of particularly vulnerable areas) is established in the integrated management plans. The process towards the management plans has been cross-sectoral including different government agencies and scientific institutions (Knol, 2010a,b; Olsen et al., 2016; Sander, 2018). The establishment of the first integrated management plan for all the marine areas was concretized in the White Paper Nr. 12 (2001–2002): Rent og Rikt Hav (NME, 2001). Following the 2001 White Paper, the integrated management plan for the Barents Sea and the Lofoten islands was ratified by the government in 2006 (Report No. 8 to the Storting (2005–2006): Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands) (NME 2006), and updated in 2011 (Meld. St. 10 (2010–2011) (NME, 2011) and in 2015 (Meld. St. 20 (2014–2015) (NMCE, 2015). The 2011 updated management plan focuses on Lofoten and Vesterålen islands, and Senja island. The 2015 updated plan focuses especially on the marginal ice

[1] Production licences are awarded in two rounds: the ordinary licensing rounds and the Awards for Predefined Areas (APAs). APAs comprise of the mature areas on the shelf i.e. areas with known geology and existing and planned infrastructure. The ordinary rounds are for the frontier parts of the Norwegian continental shelf, including the southeast and northern areas of the Barents Sea.

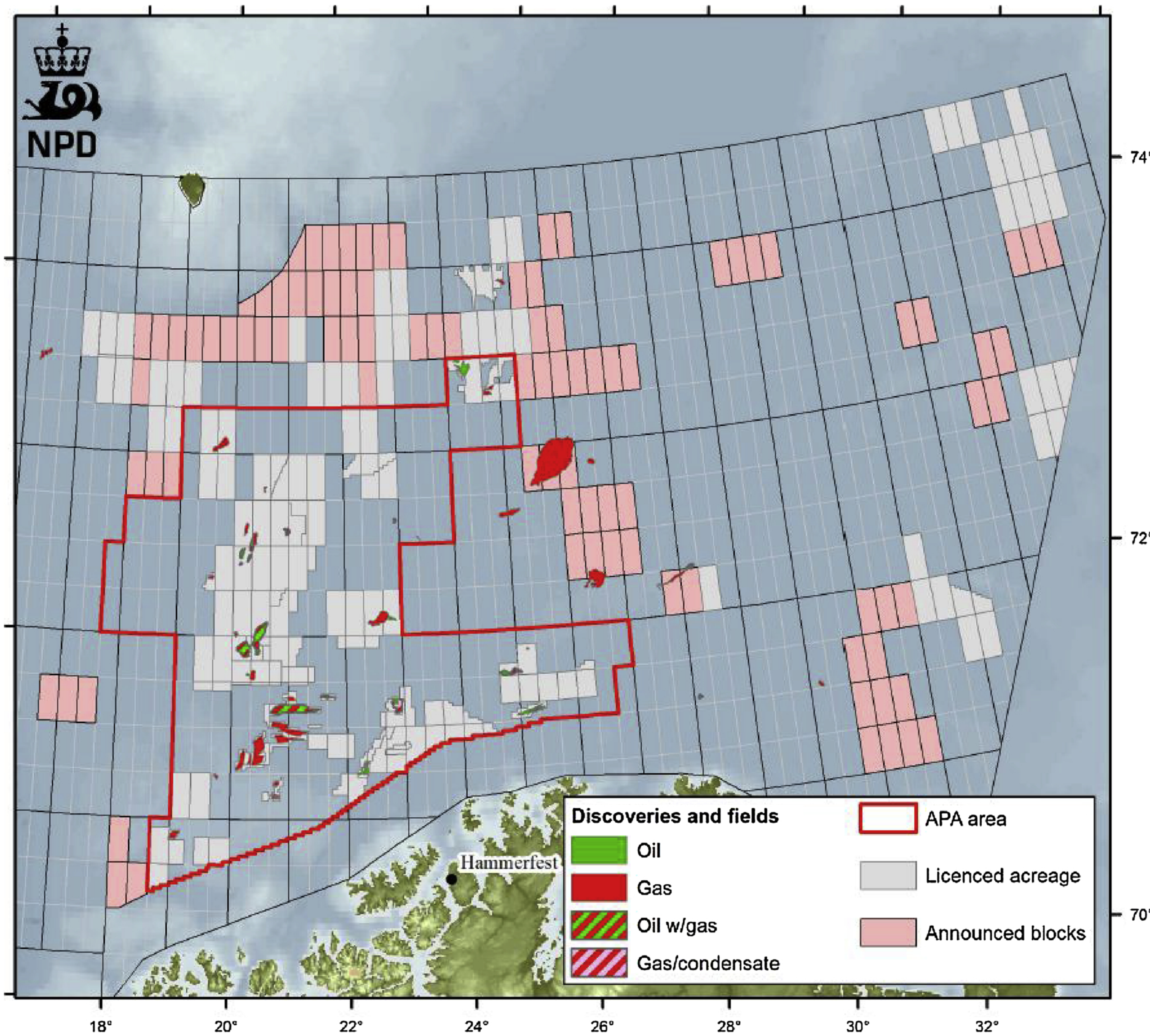

Fig. 1. Announcement of 24th licensing round (red blocks are the newly opened areas, grey ones are active exploration sites). Reprinted from Norwegian Petroleum Directorate (NPD, 2017b) with permission.

zone and on preparedness and response systems for acute pollution in icy waters. The plan also identifies the particularly valuable and vulnerable areas where restricted conditions or prohibition are set for petroleum (Fig. 2).

The newly opened areas are closer to these particularly valuable and vulnerable areas, such as the marginal ice zone (MIZ), than areas that have previously been opened for exploration and exploitation. The MIZ is identified as particularly valuable and vulnerable area in the 2006 and 2011 management plans, but in the 2015 plan, the MIZ has been delimited to better present the current ice conditions (NMCE, 2015). As the data used in the previous management plans was no longer considered as representative of the current ice conditions, the marginal ice zone was redefined in using new data available for the period 1985 – 2014. The marginal ice zone is defined to follow a line joining areas where sea ice is present on 30% of the days in April, i.e. the MIZ is delimited using a minimum ice persistence of 30%. The presence of ice means that the proportion of the sea surface covered by ice (ice concentration) is more than 15%. (NMCE, 2015).

According to the Management Plan (NMCE, 2015), the consequences of a potential oil spill depend on the type and properties of the oil released, the nature of the receiving environment and the specific circumstances of the accident, and that “the potential consequences will be most serious if a spill could affect areas where there are high densities of vulnerable species or areas of vulnerable habitat, such as the marginal ice zone and coastal waters” (NMCE, 2015). The plan also specifies that spills in the open sea could have serious impacts, especially at certain times when there are high densities of vulnerable seabirds (NMCE, 2015).

Industry risk assessments provide input to the management plans. Risk assessments are a compulsory part of the impact assessments as required by the Petroleum Act, and they need to be carried out before new areas for petroleum activities are opened (Norwegian Petroleum, 2018). The industry risk assessments are generally based on worst-case scenarios (as defined by the industry) i.e. on consequences of a potential blow-out (Hauge et al., 2014). The Barents Sea Exploration Collaboration (BASEC), which has been established by central Norwegian oil operators, aims to develop a common approach to operating in the newly opened areas (23rd concession round) in the Norwegian Barents Sea (NOROG 2018). The work of BaSEC covers also environment and oil spill preparedness: they have published a joint BaSEC risk assessment for block 7435/ 9 (situated in the 74th parallel, 380 km from the nearest land area with a distance of approximately 440 km to

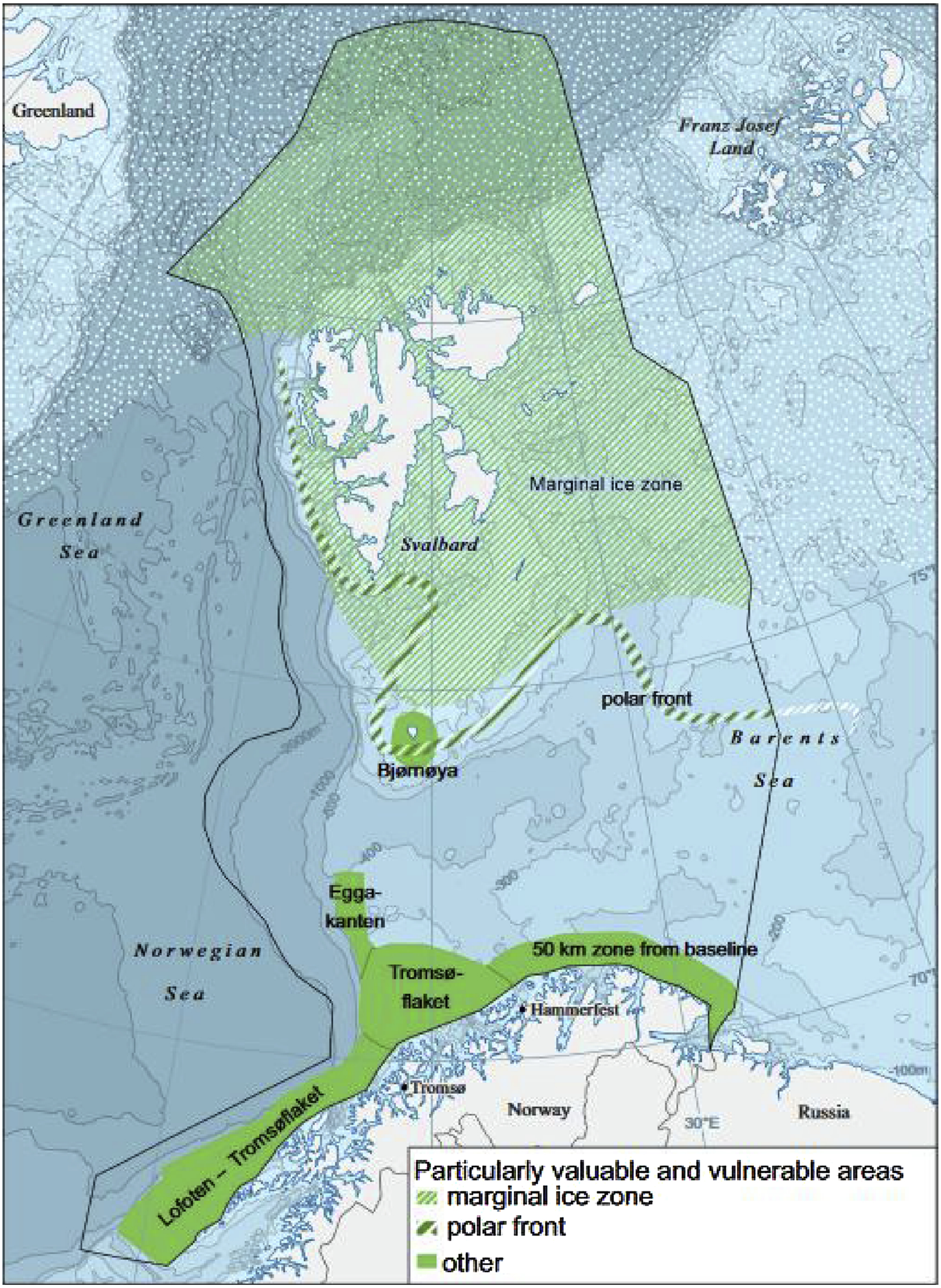

Fig. 2. Particularly valuable and vulnerable areas as defined in the 2015 management plan. The marginal ice zone is based on data on sea ice extent for the period 1985 – 2014. Reprinted from Norwegian Ministry for Climate and Environment (NMCE, 2015) with permission.

the Norwegian mainland). The BaSEC risk assessment for includes oil spill modelling of the dimensioning spill scenarios including both topside and subsea blowout scenarios (BaSEC, 2015). The environmental risk analysis is carried out by combining oil drift modelling with various environmental resource data (BaSEC, 2015).

The BaSEC risk assessments assess different environmental resources: these are referred to as Valued Ecological Components (VECs) covering seabirds, marina mammals, coastal habitats, fish, and the marginal ice zone (BaSEC, 2015). According to the risk assessment (BaSEC, 2015), the most likely impacts are limited to the open sea areas and resources at the sea surface. Risks to the marginal ice zone are considered relevant in the late winter/ early spring when ice extends at its maximum. The weather conditions affect the position of the marginal ice zone (as defined in the management plan ($\geq$15% concentration) and in case of rare weather conditions, the sea ice might move further South to cover the release location, and the oil might be trapped within/ underneath the ice. These would have consequences to the natural resources within the marginal ice zone, such as Ivory gull (*Pagophila eburnea*), which is defined as threatened species, and different marine mammal species. (BaSEC, 2015)

The risk assessments use different datasets based on different assumptions. For example, when assessing the enviro ntal risks to bird populations, the industry assessment differs from the more conservative risk assessments used in the management plans: whereas the management plan uses “average distributions” from several years of counting data and covering the total Barents Sea area (SEAPOP- data = data provided by research institutions and industry), the BASEC assessment also uses DNV GL (data provided by industry) datasets of dynamic resource modelling based on gls-logger data that provides actual, site-specific data of the location of the seabirds at a certain time of the year (BaSEC, 2015). The DNV GL datasets are considered to increase the precision and reduce the uncertainties of consequence assessments (BaSEC, 2015).

3. Theoretical framework

Conventionally, risks are considered in technical terms and understood as probabilities and consequences, but many now argue that the complex nature of risks cannot be understood or managed with traditional risk assessment tools alone (de Marchi, 2015; Klinke and Renn, 2012; Renn et al., 2011; Slovic, 2001). The central role of science in the governance of highly complex and controversial risks related to e.g. nuclear energy, genetically modified organisms, and nanotechnology has been scrutinized by a body of authors (Failing et al., 2007; Gregory et al., 2006; Jasanoff, 1998, 2003; Rowe and Frewer, 2005; Wynne, 2011; Yearley, 2000). As Gregory et al. (2006) highlight, science can provide us knowledge about the nature of issues and alert us of problems, but it cannot tell us what to do or who should be involved - more specifically, it cannot tell us about the social, cultural, or economic importance of the consequences of changes in the natural environment.

We apply risk frames as a conceptual tool to explore ambiguity related to oil spill risks in the Barents Sea. Ambiguity is often distinguished from uncertainty and defined as the differing ways on understanding and interpreting risks as well as the acceptability and/or tolerability of risks (Renn et al., 2011). Here, drawing on the work of Brugnach et al. (2008, 2011) on water resources management, ambiguity is defined as a distinct type of uncertainty that refers to the different ways of understanding, interpreting, and knowing reality (Brugnach et al., 2008; Brugnach and Ingram, 2012). Ambiguity is considered as the product of a socio-technical-environmental context, i.e. its frame (Brugnach et al., 2008; Brugnach and Ingram, 2012). The framing of a resource management situation defines the issue at stake as well as who is included and how (Brugnach et al., 2008). The processes of framing define the outcome and the direction of management processes as the formulation of a problem in a different way elicits distinct preferences, different kinds of knowledge, and points towards different solutions (Pahl-Wostl et al., 2007; Brugnach and Ingram, 2012).

Ambiguity is considered to be based on differences in 1) the type of knowledge production processes, and consequently 2) how knowledge is understood (Brugnach and Ingram, 2012). Exploring ambiguity requires the re-thinking of what constitutes as relevant knowledge and the way that knowledge production translates to policy. In contemporary knowledge production processes, knowledge is generally conceived as scientific facts that objectively represent the reality (Wynne, 2005; Jasanoff, 1998, 1995). The conventional view of knowledge posits that more knowledge results in a better picture of risk: reducing uncertainty through research leads to better understandability and control of risks (Fazey et al., 2014; Jasanoff, 1995; Sarewitz and Pielke, 2007). Further, the process of translating scientific knowledge into policy is considered linear (Nutley et al., 2007). However, this way of defining knowledge undermines other forms of knowledge and ignores the relational part of knowledge, i.e. the value-laden relational aspect that refers to e.g. who is being included or excluded from the problem understanding (Bouwen, 2001). Collaborative framing processes are essential in integrating social values into technical decisions and in coping with ambiguity (Brugnach et al., 2011; Brugnach, 2017; Lejano and Ingram, 2009; Renn et al., 2011). The integration of different types of knowledges in risk governance can contribute to developing efficient governance measures and support the legitimacy of the measures and the commitment to policy (Failing et al., 2007; Gregory et al., 2006; Jasanoff, 1998, 2003).

In order to explore the risk frames related to oil spill risk governance in the Barents Sea, we use semi-structured interviews to construct qualitative mental models. Mental modelling can help to understand complex socio-ecological problems by uncovering how stakeholders perceive the linkages between different drivers/ causes, and by visualising the different views and priorities such as competing goals and alternative management decisions (Jones et al., 2011; Voinov and Bousquet, 2010). This allows for enhancing the understanding of complex, uncertain, systems and improving communication, discussion, and debate (Haapasaari et al., 2012; Voinov and Bousquet, 2010).

Mental models are described as individually and internally held cognitive structures that are used to filter and store information and that allow individuals to reason, explain and interact with their surroundings (Jones et al., 2011). Mental models can be elicited with the use of e.g. fuzzy cognitive mapping (van Vliet et al., 2010; Özesmi and Özesmi, 2004; Jones et al., 2011); agent-based modelling (Janssen and Ostrom, 2006); or the use of Bayesian networks (BNs) (Aalders, 2008; Castelletti and Soncini-Sessa, 2007; Carriger et al., 2018; Haapasaari et al., 2012; Neil et al., 2000; Stewart et al., 2014).

Here, we elicit mental models using influence diagrams based on the logic of Bayesian networks. With the use of the influence diagram based mental modelling approach, we hope to provide insight into the governance of complex risks and examine how ambiguity and different ways of knowing can be coped with in risk governance. Bayesian networks are widely applied to decision-making in environmental and fisheries management (Aalders, 2008; Haapasaari et al., 2012; Uusitalo, 2007; Kuikka and Varis, 1997) including studies on the environmental impacts of oil spills (Lecklin et al., 2011; Nevalainen et al., 2017) and oil spill risk management (Carriger and Barron, 2011; Helle et al., 2015; Lehikoinen et al., 2015; Montewka et al., 2013). BNs can be constructed as influence diagrams by including decision and utility nodes in the network, describing the probabilistic paths from decision nodes to the utility functions. BN-based influence diagrams include both qualitative

Table 1
Interview information and the coding system *additional, shorter interviews.

Type of organisation	Code in the paper	Interview date (month and year)
Industry association	IND-1	Nov-17
Research center	RES-1	Jan-18
Municipal authority	MUN-1	Nov-17
Research center	RES-2	Nov-17
Research center	RES-3	Nov-17
Research center	RES-4	Nov-17
Governmental authorities	GOV-1	Nov-17
Municipal authority	MUN-2*	Nov-17
Locals	LOC-9* / LOC-10*	Nov-17
Fisheries association	FIS-11*	Nov-17

(graphic) and quantitative data. Here, only qualitative data was included, but similarly to other mental modelling tools, the influence diagrams could be further built into quantitative models: this aids the designing of further quantitative studies and can be a useful tool for interdisciplinary research (Carriger et al., 2018; Neil et al., 2000; Nyberg et al., 2006; Voinov and Bousquet, 2010).

For the purpose of this study, seven semi-structured interviews (each between 2–3 h) were conducted (see Table 1). The participants interviewed included an industry representative, local municipality representative, governmental authority, and four researchers (from the fields of fisheries science, maritime law, social sciences, and maritime safety and engineering). The interviewees selected were considered to be information-rich and have a good understanding of the topic. The anonymity of the interviewees was guaranteed by means of coding system (see Table 1). The interviews consisted of an introduction to the study and to the logic of mental modelling and drawing the mental models, elicitation of the interviewees' mental models including the identification of the key management measures and knowledge actions. The participants were then asked how they perceive the key impacts/ threats of oil spills in the newly opened areas. This was followed by the constructing of the influence diagrams where the participants were asked to describe 1) what should be objectives of risk governance, 2) what kind of management/ governance measures could or should be used to reach these objectives, and 3) what factors, and relationships between factors, affect achieving the objectives. Three types of variables were used to build the influence diagrams: utility variables defining the objectives (depicted as diamonds); decision variables that are directly controllable (depicted as rectangles); and the uncertain relevant variables of oil spill risk governance (depicted as ovals). The assumed strength of the relationships between different variables was depicted in arrows of different strength: a thin arrow depicted a weak effect, a medium arrow a moderate effect, and a thick arrow a strong effect.

The final part of the interview (not included in the influence diagram) comprised questions related to knowledge needs, production and communication. Here, interviewees were asked to identify the three main knowledge needs in terms of risk governance by choosing the three most important variables included in the mental models. They were then asked about the type of knowledge as well as knowledge producers they considered important in risk governance. Final question related to knowledge communication and the factors that enable or restrict knowledge sharing and communication. The interviews were recorded and transcribed as soon as possible after the interviews took place. The models were then finalized by the interviewer and the participants were given the chance to review the finalised versions afterwards. The changes included minor changes e.g. in the strength of arrows or better formulation of the written text.

The validity of the research was assessed through data triangulation: data was double-checked by asking different interviewees the same information and by corroborating interview accounts with on-site observation and the use of additional, shorter and informal, interviews *(INF 8, 9, 10, 11)*. Afterwards, the data was also cross-referenced with government documents and regulations, research, and newspaper articles.

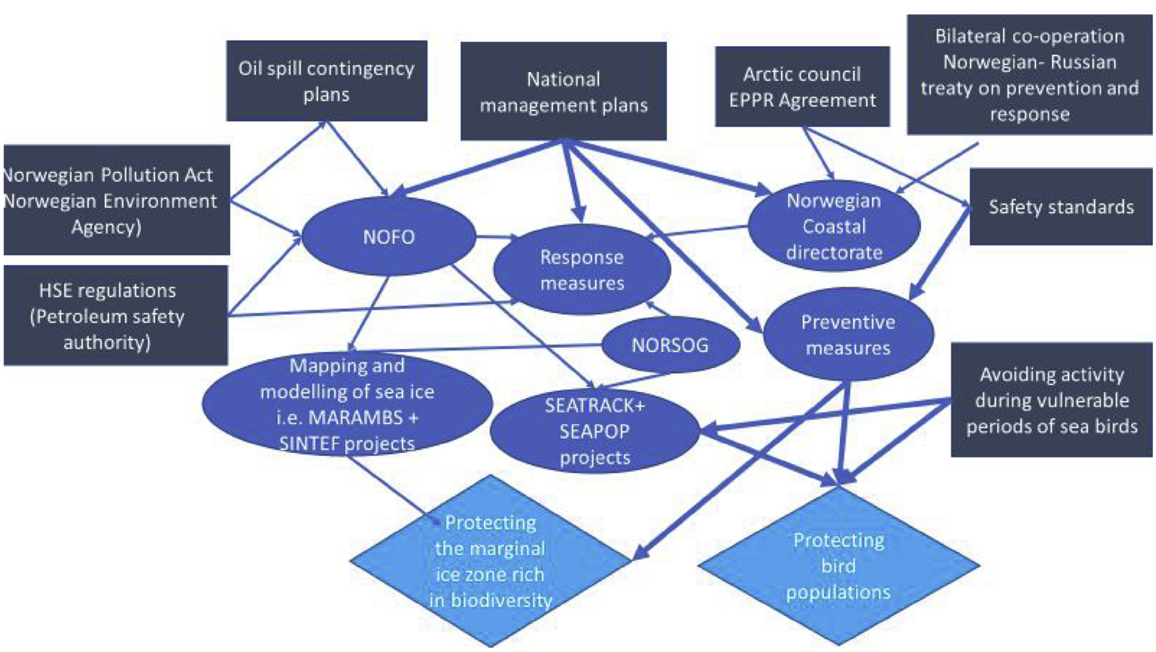

Fig. 3. Model of IND-1. Causal chains linking the measures (depicted as rectangles) and the relevant variables (depicted as ovals) to the governance objectives (depicted as diamonds). The strength of the perceived dependencies between the variables are marked with different strength arrows (thin, medium or thick arrows).

4. Risk frames

4.1. Industry association (IND-1): protect the key species and areas

The participant focused on the risk of a blow-out from offshore operations and its environmental impacts, and emphasized industry standards and the national management plans as the most important ways to achieve the environmental objectives. The overall objectives (depicted as diamond-shaped) of oil spill risk governance were to protect the environment, i.e. protecting the ecosystems linked to the marginal ice zone and the sea birds (Fig. 3; for a full list of objectives identified by the respondents, see Table A1. in Appendix A). The sea birds mentioned included globally declining ones that are protected under international convention, e.g. Guillemot (*Uria aalge*) and the Brünnich's guillemot (*Uria Lomvia*).

In order to reach the environmental objectives, the interviewee highlighted the role of the current industry safety standards and the national ecosystem-based management plan for the Barents Sea: the thick arrows linking these two measures (depicted as rectangles) to the objectives indicate that the person sees a strong dependency between the measures and achieving the objectives (Fig. 3). The person also favoured preventive measures (as indicated by the thick arrow between the preventive measures and the objectives) over response measures. National regulations and international collaboration (see Fig. 3; for a full list of measures identified by the respondents, see Table A2. in Appendix A) were seen to have a smaller role in achieving the objectives as shown by the intermediate strength arrow (Fig. 3).

The participant considered that more scientific knowledge (produced by the industry, consulting companies, universities as well as state agencies) was needed concerning the environmental impacts of oil spills and the sensitivity of organisms to oil. The participant also saw that further knowledge was needed on the movement of ocean currents and ice and the effectiveness of response measures (for a full list of knowledge needs, knowledge sources and knowledge communication, see Table A3. in Appendix A).

4.2. Research center (RES-1): complex ecosystem and species-specific impacts

The respondent stressed the environmental impacts of oil spills and considered the national management plans as the main measures to reduce the impacts. The respondent considered protecting the ecosystem in general as an objective, and more specifically the goals included preventing potential impact on pelagic juvenile fish and to vulnerable stages of Arctic species found in the marginal ice zone, such as the polar cod (*Boreogadus saida*) (Fig. 4).

The interviewee focused on the role of the management plan for the Barents Sea in reaching the environmental objectives: this is shown by the chain of intermediate and thick arrows linking management plan for the Barents Sea with the objective of protecting the ecosystem. The role of the Institute of Marine Research (IMR), under the Norwegian Ministry of Trade, Industry and Fisheries, was considered to have a strong effect (as indicated by the thick arrow) on producing knowledge of species, sensitivities, ecosystem structure and functioning, which then had a strong effect in reducing uncertainty and, in the end, protecting the ecosystem (Fig. 4). Models on early life stages of fish contributed to knowledge production: the models are based on IMR's laboratory and field research data as well as ocean circulations models (from other research institutes).

The respondent considered that more knowledge, in the form of peer-reviewed articles, was needed on the environmental impacts of oil spill e.g. on the ecosystem impacts of potential oil spills; on the species-specific sensitivity to oil; and on threshold concentrations of oil that will not lead to any effect.

4.3. Municipal authority (MUN-1): maintaining local economy is important

The respondent considered social and transport safety-related objectives important, and highlighted the need for new regulations concerning safety and industry operations to reach these objectives. The specific objectives identified were to maintain and improve transport safety (related to transport of oil as well as personnel and/ or the infrastructure), improve monitoring of maritime operations, job creation, and reducing the impact on the way of living in the coastal areas (Fig. 5).

The respondent identified several chains of strong arrows linking the measures with objectives. Regulations concerning safety were considered to have a strong effect on search and rescue (SAR) criteria for rescue operations and finally, for maintaining and improving transport safety. Establishing a permanent SAR-center in Vardo was

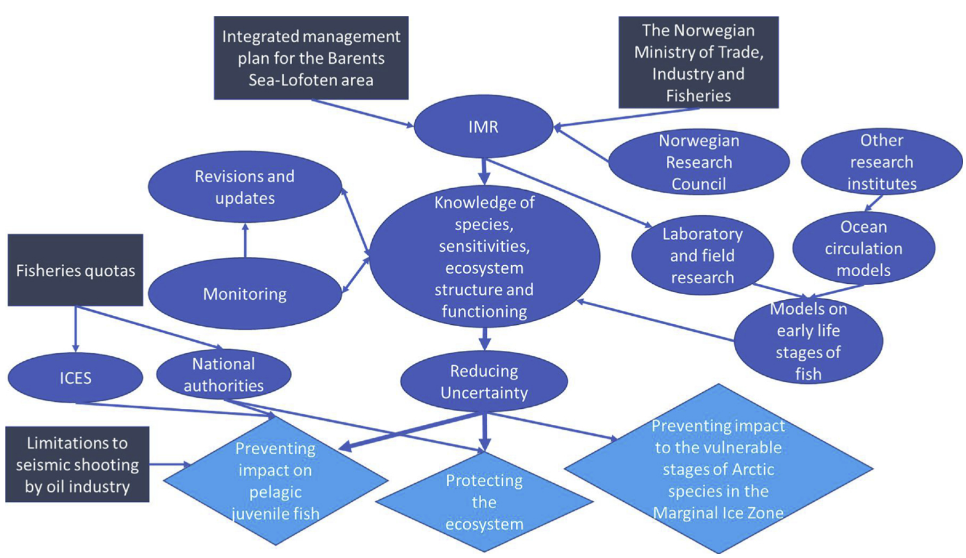

Fig. 4. Model of RES-1.

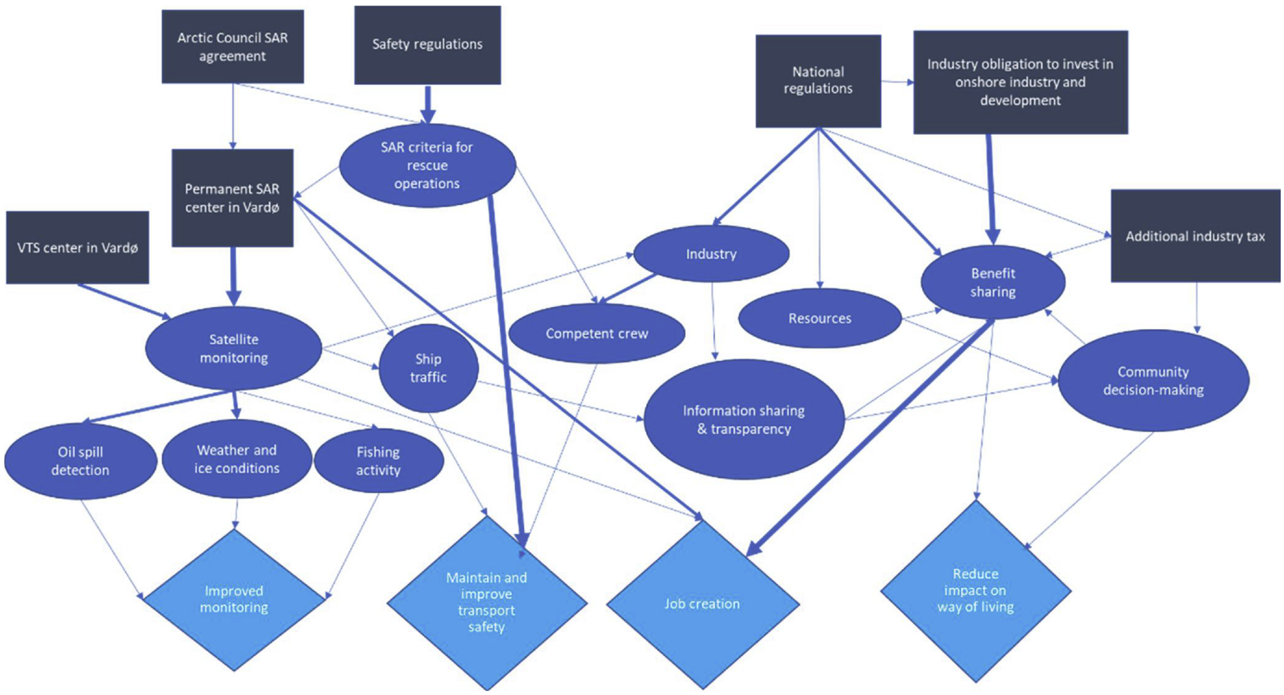

Fig. 5. Model of MUN-1.

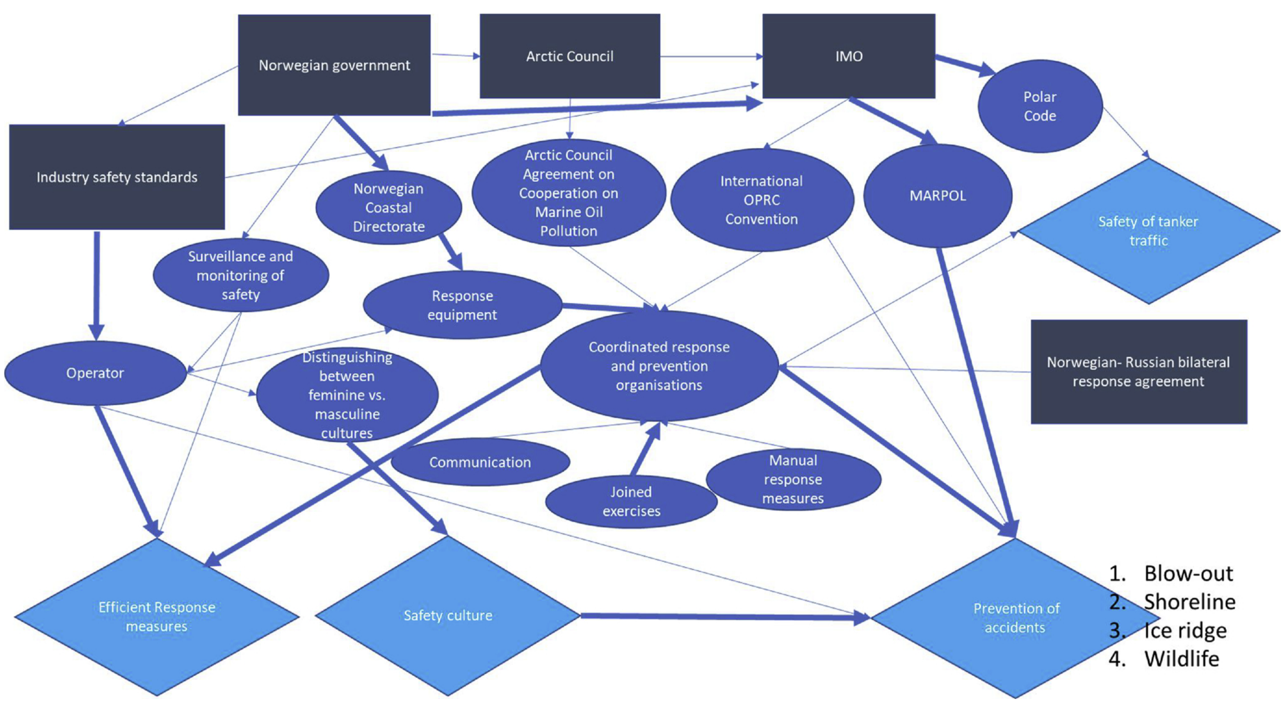

Fig. 6. Model of RES-2.

considered important – this would have a strong effect for improving satellite monitoring (for weather and ice conditions, oil spill detection and fishing activity) and in creating local jobs. The respondent also identified new measures in order to reach the social objectives, such as an industry obligation to invest in onshore industry and development (thick arrow), and an additional industry tax (thin arrow) to support local benefit sharing.

The interviewee identified new knowledge needs related to transport safety, including knowledge on weather conditions and Arctic specific conditions; the impact of those on operations (both platforms and shipping); and crew competence operating in the Arctic. Important knowledge producers included satellites, ships, and platforms. The respondent also suggested that the industry should have an obligation to provide necessary information (e.g. monitoring results) and considered establishing an open 'data bank' with different knowledge sources as a means to improve public knowledge of the operations and the risks related to those.

4.4. Research center (RES-2): preventing risks from drilling operations and shipping

The respondent focused on safety related risks and objectives, and identified a range of measures (from international and national regulations to industry safety standards, and to improving safety culture) to improve safety of both shipping and offshore drilling operations. Prevention of blow-outs was considered as the main objective (1), followed by preventing impacts on the shoreline (2), the ice ridge i.e. the ice edge (3), and the wild life (4) (Fig. 6). The other objectives included the prevention of accidents; the safety of tanker traffic; establishing safety culture; and establishing sufficient preparedness and response measures.

Coordinated response and prevention organisations were considered to have a strong effect in both prevention of accident and in terms of efficient response measures (Fig. 6). This person believed that the prevention of accidents was strongly depended on the Norwegian Coastal Directorate (under the Norwegian government): this can be seen from chain of thick links from the Norwegian Coastal Directorate to response equipment, then to coordinated response and prevention organisations and, finally, to prevention of accidents. Similarly, industry safety standards contributed to efficient response measures (thick arrow). The International Convention for the Prevention of Pollution (MARPOL) and safety culture were also considered important for the prevention of accidents.

New knowledge needs identified by participant related to response planning and safety, and included knowledge on the behaviour of oil in ice-infested waters; the effectiveness of response equipment and measures; and safety culture. The industry and research bodies were considered as important and relevant knowledge providers.

4.5. Research center (RES-3): ineffectiveness of the current response methods

The respondent emphasized environmental, social, economic and safety-related risks and objectives. Similarly to the previous respondent, here, too, the importance of coordinated oil spill response system was highlighted. The main risks included the impacts of a potential oil spill to the shoreline, the living organisms (on the shore and in the water column), and fisheries and tourism. The specific objectives included prevention of accidents and effective response, which both had a strong effect on the most important objective: protecting human health, environment, and investments (in the order of importance).

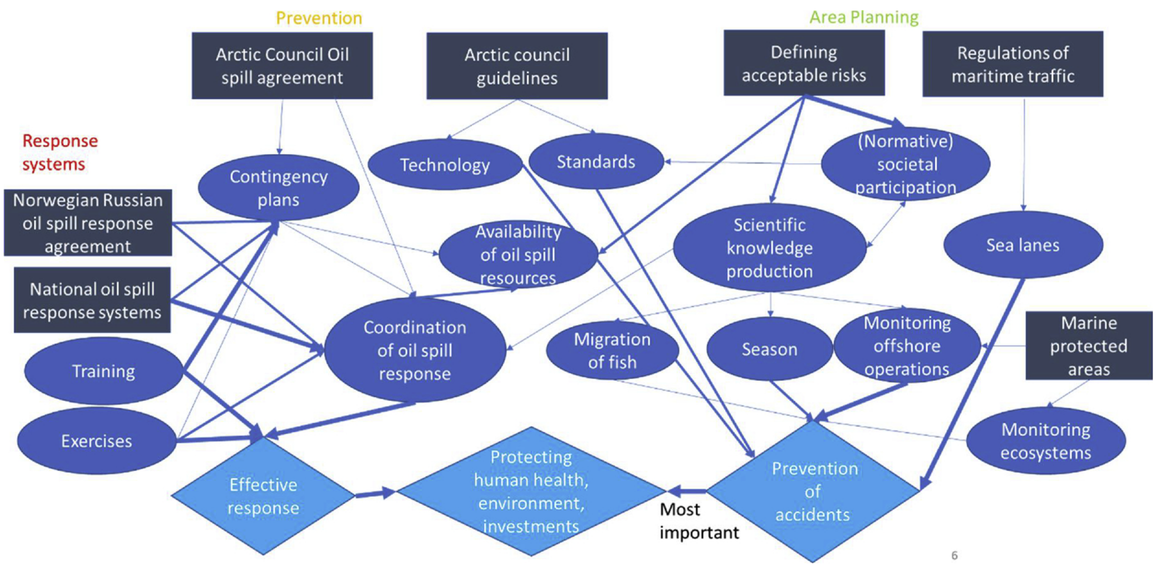

Fig. 7. Model of RES-3.

The respondent emphasized the need for a well-organized oil spill response system in the Barents Sea both at national and bi-lateral (Norwegian-Russian co-operation) level. The person believed that training and exercises, both national and joint with Russia, were strongly linked (thick arrows) to coordination of oil spill response. In addition, defining acceptable risks was linked to the prevention of accidents: while scientific knowledge production was seen as important, normative societal participation was also considered necessary in terms of defining and assessing the acceptability and tolerability of risks.

Knowledge needs identified ranged from the ecosystem impacts of a potential oil spill to the performances and effectiveness of response technology, and to the coordination of effective response. While different governmental agencies as well as universities were considered as important knowledge producers, the interviewee emphasized that there was a need for public debates, hearings, and meetings to support wider societal participation in assessing risks related to the oil industry operations. Updating management plans and monitoring (coordinated by the Coastal administration) were included as important ways of communicating knowledge.

4.6. Research center (RES-4): new rules on participation needed

Here, environmental, social, economic, and safety-related risks and objectives were highlighted. The respondent emphasized the need for updating and improving the national regulations related to risk governance i.e. the decision-making process itself. The environmental risks included the impacts to the ecosystem of the marginal ice zone, but also impacts of produced water (water produced as a by-product along with oil and gas) to the environment. Social and economic risks included potential impacts to fishing industry and coastal communities, and the financial risks of the offshore operations. The objectives identified were "clean environment", "safety and security", "preparedness and procedures culture". The objectives also included transparent and participatory governance of risks (Fig. 8).

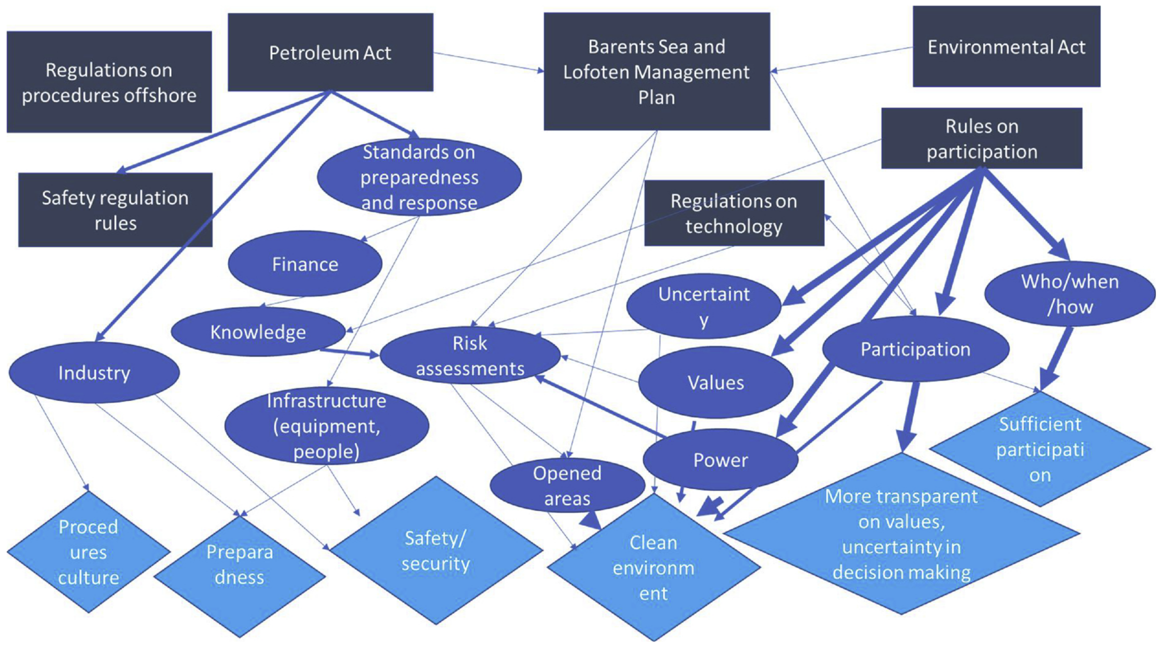

Fig. 8. Model of RES-4.

As a single policy action, the rules on participation dominate, as it has several strong and short pathways to the objective variables e.g. the thick arrow linking “rules on participation”, “participation” and the objective of transparent decision-making. The respondent stressed that more attention should be paid on the issues of uncertainty, societal values, and power, and how these relate to risk assessments and the decision-making processes of opening (or not opening) new areas for operations. Opened areas and power relations had strong effect on the object of clean environment, but in the current situation, these were considered as negative effects.

In terms of knowledge needs, the interviewee considered that more attention should be paid on the uncertainty, ambiguity, and power relations in decision-making, as well as on the strengths and limitations of scientific knowledge in decision-making processes. Wide range of knowledge producers were considered to be important, including research centres as well as local and traditional knowledge holders. Providing new venues or forums for stakeholder interaction were considered important for knowledge sharing.

4.7. Governmental authority (GOV-1): risks to traditional livelihoods and culture

The respondent stressed the environmental and socio-cultural risks: petroleum industry operations contribute to climate change, and the environmental impacts of climate change have serious implications on Sami livelihood and Sami culture. The prevention of oil spills was the most important objective and it was linked to the objective of ensuring environmental and cultural sustainability. The third objective was ensuring effective response plans (Fig. 9).

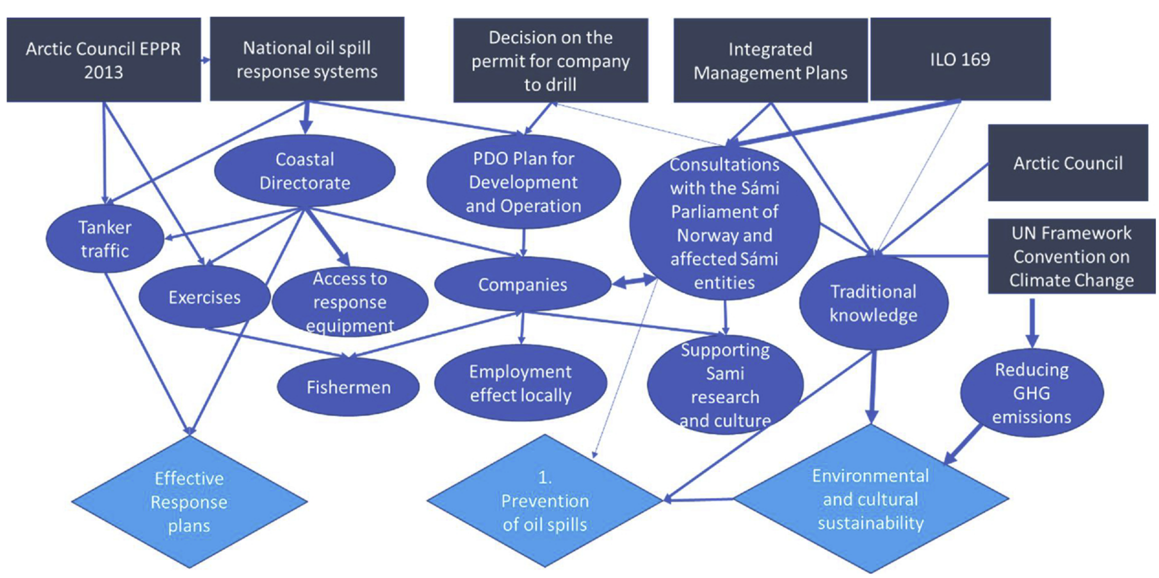

Fig. 9. Model of GOV-1.

The interviewee highlighted the importance of international regulations as indicated by the strong and intermediate paths linking the regulations with the objective of reaching environmental and cultural

Table 2
Summary of objectives as identified by the participants.

	IND-1	RES-1	MUN-1	RES-2	RES-3	RES-4	GOV-1
Protecting the environment	○	○		○	○	○	○
Prevention of accidents				○	○	○	○
Effective response plans				○	○		○
Safety			○	○		○	
Establish safety culture				○		○	
Job creation and reducing impact on way of living			○				
Transparent governance						○	
Sufficient participation						○	

sustainability. The UN Convention concerning Indigenous and Tribal Peoples (ILO 169), ratified by Norway in 1990, was seen to have a strong effect on obligatory consultations with the Sami Parliament of Norway or with affected Sami entities before undertaking projects that can directly affect them. The consultations were seen to contribute to the use of traditional knowledge, which was considered to have a strong effect on environmental and cultural sustainability. Also the impact of the UN Convention on reducing GHG emissions was sees as important (thick arrow) for environmental and cultural sustainability.

The interviewee considered that the use of indigenous knowledge in addition to scientific knowledge could improve the governance of oil spill risks. Relevant knowledge producers included different Sami institutions (e.g. Sami Center of University of Tromso). The participation of the Sami Parliament in the work of the Norwegian research council was seen as an important channel to share and promote traditional knowledge. Other ways of improving knowledge dissemination included the use of traditional knowledge in impact assessments.

5. Discussion

This study indicates that the current risk governance framework inadequately addresses the multiple risk frames included in this analysis. The current oil spill risk governance framework in the Barents Sea can be considered comprehensive spanning from the ecosystem-based management plans and technical risk assessments to the different regulatory measures and the use of strict industry standards. The study, however, indicates that the existing governance framework fails to treat the ambiguity around oil spill risks: the current risk assessments and risk management do not reflect on the multiple ways in which the participants in this study 1) frame the problem situation, 2) how they identify different measures to manage risks, and 3) what are considered as key knowledge needs and knowledge producers by the participants. This is problematic since ignoring and rejecting the various perspectives can block the formulation of effective solutions. We suggest that collaborative knowledge production and social learning are needed to move towards developing shared understanding of the problem situation.

This study demonstrates that the current management approach focuses on the acute risks to key species, but as the results illustrate, the participants in this study defined risks and governance objectives in multiple ways (for a summary of objectives, see Table 2; for a full list of objectives see Table A2. in Appendix A). As demonstrated earlier, the management plans and the industry risk assessments both frame risks in a very specific way by focusing on worst-case scenarios (blow-out scenarios) and on the immediate effects of an oil spill on key species in the areas that are defined as particularly valuable and vulnerable in the management plans, i.e. the marginal ice zone. The low probability of risks as well as the history of few, preceding, major-scale accidents is also highlighted. The dominant position of the industry in assessing and defining the risks is further supported by previous studies on petroleum operations to the Lofoten and Senja islands (Hauge et al., 2014).

However, what counts as significant when evaluating and assessing risks as well as what constitutes as an appropriate solution are not merely scientific questions but value-based (Hauge et al., 2014; Brugnach, 2017). The influence diagrams reveal the complex nature of risks by demonstrating considerable differences in the interests of the different societal stakeholders i.e. differing values and ways of knowing. The participants in this study emphasized a wide range of environmental (complex ecosystem and species-specific impacts, impacts of routine operations e.g. produced waters, risk of seismic shooting to fish), economic (impacts to fishing industry and tourism, financial risks of the operations to Norwegian taxpayers), and social risks, including both the long-term local and global consequences of offshore drilling operations e.g. how offshore drilling contributes to climate change. Consequently, also the objectives of risk governance differed among the participants (See Figs. 3–9; Table 2). Protecting the environment and preventing oil spill from taking place are objectives shared by most of the participants. However, protecting the environment was defined in various ways (See Table A1. in Appendix A). In addition, some of the objectives were model-specific.

The influence diagrams shed light on how the participants perceive and understand the system as a whole and how the system can be manipulated so that the objectives can be reached. The strength of the arrows (between the different measures, variables and objectives) describes how strong effect each of the decision variables has in pushing the system to a desired direction. Strong arrows or strong chains of arrows linking measures to the governance objectives demonstrate that effective ways to control the risks exist or can be developed. A wide range of measures were identified in this study (See Figs. 3–9; Table 3; for a full list of measures, see Table A2. in Appendix A). A summary of the main measures is presented in Table 3, where the measures are categorized into strong, moderate, and weak measures. The results indicate that the current management measures (i.e. the management plans, industry safety standards, and prevention and response system) were identified by the respondents as ways of reaching some of the objectives, but were not always considered as strong measures. For example, the management plan was identified by several respondents, but only one respondent considered it to be strongly linked to another variable (see Table 3). In addition, new measures were considered necessary. It must, however, be noted that the 'overall' effectiveness of the measure depends on both the strength of the arrows and the length of the chains as every variable adds weight to the chain but also decreases the precision to achieve the desired aims. A further, quantitative, analysis could provide a more detailed picture of the relationships between the variables.

The influence diagrams differ in the level of complexity, i.e. in the number of variables included and in the number of links identified between these variables. For example, RES-1 mainly discusses the risks to juvenile fish in the Barents Sea. Similarly, the influence diagram of GOV-1 focuses on the risks of offshore drilling and climate change to the Sami culture and livelihoods. One may conclude, that it is natural that participants restrict the model only to such variables, which have a meaning in how well their specific aims are achieved.

The influence diagrams illustrate the socially constructed nature of risks as well as the inherently subjective nature of risk assessments. Özesmi and Özesmi (2004) suggest that by examining the structure of

Table 3
Summary of the main measures as identified by the respondents: dark blue dots refer to strong measures that are linked with at least one thick arrow to another variable, light blue dots refer to moderate measures linked with at least one medium arrow, and transparent dots refer to weak measures linked with thin arrows *indicates new measures suggested by the respondents.

	IND-1	RES-1	MUN-1	RES-2	RES-3	RES-4	GOV-1
National management plans	●	◉				○	◉
Industry safety standards	●			●			
National oil spill response system	◉				●		●
National industry regulations	◉		●	●		◉	
Norwegian-Russian oil spill response agreement	◉			○	◉		
Establishing Search and Rescue (SAR) center in Vardo*			●				
Arctic Council guidelines and agreements	◉		◉	○	○		◉
International Shipping regulations			●	●	○		
The UN Convention concerning Indigenous and Tribal Peoples (ILO 169)							●
UN Framework Convention on Climate Change							●
Rules on participation*						●	
Defining acceptable risks*					●		
Industry obligation to invest in onshore industry and development*			●				

mental maps, we can identify groups who can act as "catalyst for change": these include participants that perceive more relationships and thus have more options to change the system. Defining and assessing risks can be seen as an exercise in power: the dominant bodies have the power to define both the risks and the solutions (Slovic, 2001). As shown above, the participants identify ways to change the current risk governance framework, but their actual capacity to do so depends on social, political and economic factors (Özesmi and Özesmi, 2004).

In sum, the influence diagrams provided a valuable tool for exploring ambiguity related to a complex risk and presenting risk frames in a clear, visual, form. While the participants were given an introduction to constructing influence diagrams based on the Bayesian network logic, the diagrams show some differences e.g. in what constituted as a controllable variable according to the participant or what the arrows between the variables signified. This may be due to various reasons such as issues in communication between the interviewer and the participant and, consequently, how well the logic was understood by each of the participants. It must also be remembered, that modelling tools, such as influence diagrams, are always simplifications, and are not generally good at capturing all the nuances and small details in a system. The benefit of the method also includes that it can be quantified in future work thus supporting interdisciplinary work by using raw data, simulation models or expert judgements. In sum, the networks were powerful tools for providing general overview of a problem or issue.

The lack of knowledge can obstruct the adequate assessing of risks (AMAP, 2017a). The influence diagrams demonstrate the limited knowledge of the system as a whole (see also Table 4 for a list of the

Table 4
The main knowledge needs identified by the respondents.

IND-1	Movement of ocean currents and ice; Oil spill impacts and sensitivity of organisms; Effectiveness of response measures
RES-1	Ecosystem impacts; Species specific sensitivity to oil; Threshold concentrations of oil that will not lead to any effect; The effects of management actions
MUN-1	Weather conditions Arctic specific conditions; Impact of those on operations (both platforms and shipping); Crew competence
RES-2	Behaviour of oil in ice-infested waters; Developing response equipment and measures; Safety culture
RES-3	Ecosystem impacts; Behaviour of oil in ice infested waters; Weather conditions and their impact on technology; Performances and effectiveness of technology; Defining acceptable criteria Coordination of effective response
RES-4	Uncertainty and ambiguity in decision-making; Strengths and limitations of objective knowledge; Power relations
GOV-1	Indigenous knowledge

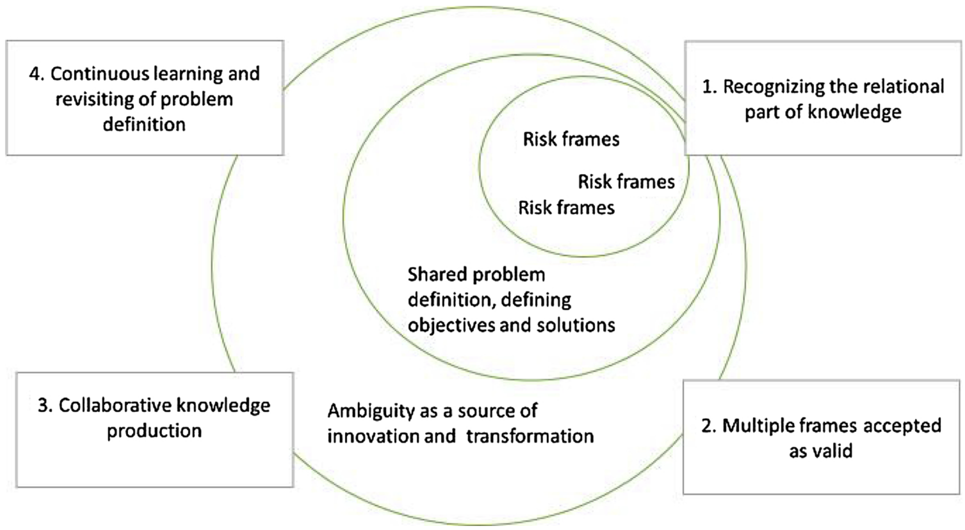

Fig. 10. Towards collaborative knowledge production and learning where ambiguity is resolved by creating a connected frame that represents a shared view on the problem. Adapted from figure created by Chapin et al (2009) and the work of Brugnach and Ingram (2012).

main knowledge needs). For example, in the newly opened areas, the current response measures are considered largely ineffective (RES-2; RES-3), but at the same time the public knowledge on the level of effectiveness is considered poor (RES-3). The lack of sufficient access to response equipment in the Finnmark region hinders the clean-up operation should a major spill happen (RES-3, GOV-1). In addition, the consequences are not only limited to Norway, but oil spills would have cross-border effects. This is problematic especially since no comprehensive knowledge exists on impacts of Arctic marine oil spills (Mäkinen and Vanhatalo, 2018; Nevalainen et al., 2018; NMPE, 2017a,2017b) and there is no existing oil spill compensation agreement between Norway and Russia (NMPE, 2017a,2017b).

Furthermore, the consequences of a potential oil spill to different marine species and the ecosystem are uncertain and difficult to analyse. As shown by previous research (Knol, 2010a, 2010b), while uncertainties are recognized by the industry and in the management plans, they are not explicitly addressed but turned into new knowledge needs i.e. calls for more research. Even though uncertainties related to the risk of a blow-out and the potential impacts to the key species are considered in the industry risk assessments, these are considered as controllable with the development and use of new technologies, e.g. by using dynamic resource modelling (based on Global Land Surveys (gls)-logger data provided by industry itself) in the BaSEC industry to assessments to improve the accuracy of data on the location of seabirds. The dominant approach to assessing and managing risks thus confirms to the conventional view of knowledge where reducing uncertainty through research is considered to lead to better understanding and control of risks and where scientific knowledge can be translated into policy in a linear manner.

Under the current governance framework, the dominant risk frame defines both how risks are defined and how relevant knowledge is understood and who/what are considered as important knowledge producers. This becomes especially apparent in the debate around how to define the marginal ice zone (MIZ). The MIZ is identified as particularly valuable and vulnerable area, but in the 2015 management plan, the MIZ has been delimited to better present the current ice conditions. This has allowed for the opening of new areas for drilling operations further in the North. However, as the ice edge is dynamic, defining the area is a complex issue, where the prediction of future ice cover is difficult. The ice edge can also be considered as a social construct that can be defined in various ways (RES-4). The re-definition of the marginal ice zone was criticized by environmental organisations as well as Polar Institute and the Environmental Agency. They have also consistently advised against the opening of the northernmost blocks in the 23rd and 24th licensing round (NMPE, 2017; Greenpeace, 2017). Finally, the decision to delimit the marginal ice zone was rejected by the Norwegian Parliament and the government was ordered to revisit the definition (Stortinget, 2015). Here, recognizing the relational part of knowledge and the limits of science is important. The decision over how to define the MIZ is not merely a scientific question and objective, but highly value-laden and polemic.

To better cope with diversity of values and different knowledge systems, we propose that there is a need for acknowledging the limits to one's knowledge and to develop and support inclusive participative decision-making processes (Fig. 10).

We posit that instead of accepting only one valid frame, we need to move towards creating a connected frame and developing shared understanding of problem situation and solutions where multiple frames and multiple ways of knowing are considered relevant in governance/decision-making processes (Brugnach et al., 2008; Failing et al., 2007; Slovic, 2001). Examples ranging from collaborative water management in California (Lejano and Ingram, 2009) to coastal governance in Australia (Clarke et al., 2013) and participative planning processes in Alaska (Robards et al., 2018) highlight that integrating different worldviews and perspectives are essential in solving complex socio-ecological problems. Further studies are needed at a more detailed level to discover e.g. how collaborative knowledge production could be supported and implemented in practice in the Norwegian context.

Collaborative knowledge production processes go beyond the calls for greater participation and approaches that do not focus on power relations or on the need for change (Brugnach, 2017; Evans and O'Brien 2015). Instead of presenting ambiguity and diversity of views as sources of conflict that need to be avoided, ambiguity may be considered as a source of innovation and creativity as well as an opportunity for transformation (Dewulf and Bouwen 2012). Influence diagrams can be used to facilitate social learning allowing the stakeholders to represent their thinking at multiple levels (Chapin et al., 2009; Henly-Shepard et al., 2015; Özesmi and Özesmi, 2004). Social learning can support transformative processes: multi-loop learning puts focus on questions such as "are we dealing with the right problem" forcing the participants to reflect on governance norms and principles and requires integrating different ways of knowing (Armitage et al. 2007). While new alternative, e.g. post-petroleum, pathways have already materialized at local/ regional level (UNIIN-BARENTS, 2018; Dale and Kristoffersen, 2018), at national level, petroleum industry is still considered a key source for future economic security (Ministry of Petroleum and Energy 2011; Dale, 2016; Dale and Kristoffersen, 2018).

6. Conclusions

Opening new areas for petroleum industry in the Arctic remains a controversial issue. This study suggests that further attention should be paid on the process of framing risks and on the socially constructed nature of risks. With the use of influence diagrams based mental modelling tools, we study the way risks are understood and defined, and how the measures to reduce those risks are identified. We also analyse the type of knowledge and knowledge sources that the risk frames are based on.

Our analysis shows that the current governance framework is unapt to integrate the multiple risk frames and knowledge systems into decision-making processes. Further attention should be paid on the limits of science in solving inherently value-based socio-ecological problems. This should be an integral part of the process and design of e.g. the new management plans, such as the 2020 updated management plan for the Barents Sea. Questions such as who should take part in identifying and evaluating risks; who are seen as relevant or as ‘experts’ in assessing risks and who are not; what governance measures are considered as important; and who should be involved to ensure the legitimacy of the decisions, need to be explored when making decisions over opening new areas for maritime industry operations. Finally, we posit that collaborative knowledge production processes and social learning are needed to better cope with ambiguity. Recognizing the validity of the different risk frames is the first step forward. We suggest that ambiguity plays a key role as a source of innovation and in transformation towards constructing sustainable societies.

Declarations of interest

None.

Acknowledgements

We would like to thank the interviewees who participated in this study. This work was funded by the Lloyd's Register Foundation (Agreement 28/5/2013). The Lloyd's Register Foundation is a charitable foundation, helping to protect life and property by supporting engineering-related education, public engagement and the application of research. The work by AL and SK was supported by the Strategic Research Council (SRC) at the Academy of Finland, under the project “Creative adaptation to wicked socioenvironmental disruptions” (WISE) (decision number 312627).

Appendix A

Table A1
Objectives (categorized under general headings) identified by the respondents.

		IND-1	RES-1	MUN-1	RES-2	RES-3	RES-4	GOV-1
Protecting the environment	**Protecting the marginal ice zone**	X						
	Protecting sea birds	X						
	Preventing impact on pelagic juvenile fish		X					
	Protecting the ecosystem		X					
	Preventing impact to vulnerable stages of Arctic species in the MIZ		X					
	Preventing impact on shoreline, ice edge, and wildlife				X			
	Protecting human health, environment, investments					X		
	Clean environment						X	
	Sustainable operations (economic, environment, culture)							X
Prevention of accidents	**Preparedness**						X	
	Prevention of accidents				X	X		
	Prevention of oil spills							X
Effective response plans	**Efficient Response**				X	X		
	Effective response plans							X
	Improved monitoring			X				
Safety	**Maintain and improve transport safety**			X				
	Safety/ security						X	
	Safety of tanker traffic				X			
	Establish safety culture				X			
	Procedures culture						X	
Other	**Job creation and reducing impact on way of living**			X				
	Transparent governance						X	
	Sufficient participation						X	

Table A2
Measures (categorized under general headings) as identified by the respondents * indicates new measures.

		IND-1	RES-1	MUN-1	RES-2	RES-3	RES-4	GOV-1
National	**Management plan for the Barents Sea**	X	X				X	X
	Petroleum Act						X	
	The Norwegian Pollution Act						X	
	HSE regulations			X				
	Regulations on participation*						X	
	Fisheries quotas		X					
	Industry safety standards	X			X			
	Contingency plan and infrastructure	X		X	X	X		X
	Temporal and spatial restrictions in industry activity	X	X					
	Marine protected areas					X		
	Plan for Development and Operation (POD)							X
International	**International Maritime Organisation (IMO) regulations**				X			
	Arctic Council				X	X		X
	Arctic Council EPPR Agreement					X		X
	Search and Rescue (SAR) agreement			X				
	Joint Norwegian-Russian Contingency Plan	X			X	X		
	UN Framework Convention on Climate Change							X
	The UN Convention concerning Indigenous and Tribal Peoples (ILO 169)							X
	Finnmark Act							X
Other	**Establishing Search and Rescue (SAR) center in Vardo***			X				
	Improved coordinating of response exercises and training *							
	Communication *							
	Industry obligation to invest in onshore industry and development *			X				
	Industry tax for local development *			X				
	Rules on participation*						X	
	Defining acceptable risks					X		

Table A3
Knowledge needs, knowledge producers, and knowledge communication.

	Knowledge needs	Relevant knowledge producers / knowledge sources	Communication
IND-1	Movement of ocean currents and ice Oil spill impacts and sensitivity of organisms Effectiveness of response measures	Industry, consulting companies State agencies Universities	Funding from Research Council and industry Cooperation between industry members e.g. forums and networks Peer-reviewed articles Cooperation with fishers
RES-1	Ecosystem impacts Species specific sensitivity to oil Threshold concentrations of oil that will not lead to any effect The effects of management actions	Peer-reviewed journals	The management plan revision groups Scientific articles, newspapers
MUN-1	Weather conditions Arctic specific conditions Impact of those on operations (both platforms and shipping) Crew competence	Satellites, ships, platforms	Cooperation with industry and the state Data bank public knowledge Obligation for the industry to provide information
RES-2	Behaviour of oil in ice-infested waters Developing response equipment and measures Safety culture	Industry Research bodies	Disseminating knowledge actively; commercial forces important
RES-3	Ecosystem impacts Behaviour of oil in ice infested waters Weather conditions and their impact on technology Performances and effectiveness of technology Defining acceptable criteria Coordination of effective response	1) knowledge production = agencies and universities 2) societal participation in defining acceptable risks	Updating management plans and monitoring (coastal administration responsible) Public debates, hearings and meetings Media Active scientists
RES-4	Uncertainty and ambiguity in decision-making Strengths and limitations of objective knowledge Power relations	Wide range of knowledge producers	Debate, venues, forum Future scenarios
GOV-1	Indigenous knowledge	Sami institutions Art and culture	Arctic Council Impact assessments Collaboration with NGOs Norwegian research council

References

Aalders, I., 2008. Modeling Land-use decision behavior with Bayesian belief networks. Ecol. Soc. 13 (1) pp. 16.

AMAP, 2017a. Adaptation Actions for a Changing Arctic: Perspectives from the Barents Area. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway (Accessed 1 November 2017). http://www.amap.no/documents/doc/Adaptation-Actions-for-a-Changing-Arctic-Perspectives-from-the-Barents-Area/1604.

AMAP, 2017b. Snow, Water, Ice and Permafrost in the Arctic. Summary for Policy-Makers. Arctic Monitoring and Assessment Programme (AMAP), Oslo, Norway (Accessed 26 April 2017). http://www.amap.no/documents/doc/Snow-Water-Ice-and-Permafrost.-Summary-for-Policy-makers/1532.

Arctic Council, 2009. Arctic Marine Shipping Assessment 2009 Report. (Accessed 16 January 2017). https://oaarchive.arctic-council.org/handle/11374/54.

Bambulyak, A., Rudiger, U., von Bock und Polach, R., Sören, E., Sydnes, A., 2014. Challenges with oil spill risk assessment in arctic regions: shipping along the Northern Sea route. ASME 2014 33rd International Conference on Ocean, Offshore and Arctic Engineering, 4B: Structures, Safety and Reliability (OMAE2014-24419). https://doi.org/10.1115/OMAE2014-24419.

BaSEC, 2015. Environmental Risk Assessment for Oil Blowout from Exploration Drilling in the Barents Sea South -East. (Accessed 11 June 2018). https://www.norskoljeoggass.no/globalassets/dokumenter/miljo/barents-sea-exploration-collaboration/basec-rapport-7a—miljorisikoanalyse-av-blokk-7435-9-i-barentshavet-sorost.pdf.

Blanchard, A., Hauge, K.H., Andersen, G., Fosså, J.H., Grøsvik, B.E., Handegard, N.O., Kaiser, M., Meier, S., Olsen, E., Vikebø, F., 2014. Harmful routines? Uncertainty in science and conflicting views on routine petroleum operations in Norway. Mar. Policy 43, 313–320. https://doi.org/10.1016/j.marpol.2013.07.001.

Bouwen, R., 2001. Developing relational practices for knowledge intensive organizational contexts. Career Dev. Int. 6 (7), 361–369.

Brugnach, M., 2017. The space in between: where multiple ways of knowing in water management meet. J. Southwest 59 (1), 34–159. https://doi.org/10.1353/jsw.2017.0005.

Brugnach, M., Ingram, H., 2012. Ambiguity: the challenge of knowing and deciding together. Environ. Sci. Policy 15 (1), 60–71. https://doi.org/10.1016/j.envsci.2011.10.005.

Brugnach, M., Dewulf, A., Pahl-Wostl, C., Taillieu, T., 2008. Toward a relational concept of uncertainty: about knowing too little, knowing too differently, and accepting not to know. Ecol. Soc. 13, 2. https://doi.org/10.5751/ES-02616-130230.

Carriger, J.F., Barron, M.G., 2011. Minimizing risks from spilled oil to ecosystem services using influence diagrams: the deepwater horizon spill response. Environ. Sci. Technol. 45 (18), 7631–187639. https://doi.org/10.1021/es201037u.

Carriger, J.F., Dyson, B.E., Benson, W.H., 2018. Representing causal knowledge in environmental policy interventions: advantages and opportunities for qualitative influence diagram applications. Integr. Environ. Assess. Manage. 14 (3), 381–394. https://doi.org/10.1002/ieam.2027.

Castelletti, A., Soncini-Sessa, R., 2007. Bayesian networks and participatory modelling in Water Resource management. Environ. Modell. Software 22 (8), 1075–1088. https://doi.org/10.1016/j.envsoft.2006.06.003. Bayesian networks in water resource modelling and management.

Chapin III, Stuart, F., Kofinas, G.P., Folke, C. (Eds.), 2009. Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer-Verlag, New York. www.springer.com/us/book/9780387730325.

Chateauraynaud, F., 2009. Public controversies and the pragmatics of protest: toward a ballistic collective action. EHESS, Paris.

CICERO, 2017. Redusert Oljeutvinning Som Klimatiltak: Faglige Og Politiske Perspektiver." Policy Note 2017: 01. (accessed 19 October 2018). https://brage.bibsys.no/xmlui/bitstream/handle/11250/2434201/Policy%20Note%202017%2001%20final%20web.pdf?sequence=1&isAllowed=y.

Clarke, B., Stocker, L., Coffey, B., Leith, P., Harvey, N., Baldwin, C., Baxter, T., et al., 2013. Enhancing the knowledge–governance interface: coasts, climate and collaboration. Ocean Coastal Manag. 86, 88–99. https://doi.org/10.1016/j.ocecoaman.2013.02.009.

Dale, B., 2016. Governing resources, governing mentalities. Petroleum and the Norwegian integrated ecosystem-based management plan for the Barents and Lofoten seas in 2011. Extr. Ind. Soc. 3 (1), 9–16. https://doi.org/10.1016/j.exis.2015.10.002.

Dale, B., Kristoffersen, B., 2018. Post-petroleum security in a changing Arctic: narratives and trajectories towards viable futures. Arctic Rev. Law Polit. 9, 244–261. https://doi.org/10.23865/arctic.

Eriksen, E., Gjøsæter, H., Prozorkevich, D., Shamray, E., Dolgov, A., Skern-Mauritzen, M., Stiansen, J.E., Kovalev, Yu., Sunnanå, K., 2017. From single species surveys towards monitoring of the Barents Sea ecosystem. Prog. Oceanogr. 166, 4–14. https://doi.org/10.1016/j.pocean.2017.09.007.

Failing, L., Gregory, R., Harstone, M., 2007. Integrating science and local knowledge in environmental risk management: a decision-focused approach. Ecol. Econ. 64 (1), 47–60. https://doi.org/10.1016/j.ecolecon.2007.03.010.

Fazey, I., Bunse, L., Msika, J., Pinke, M., Preedy, K., Evely, A.C., Lambert, E., Hastings, E., Morris, S., Reed, M.S., 2014. Evaluating knowledge Exchange in interdisciplinary and multi-stakeholder research. Global Environ. Change 25, 204–220. https://doi.org/10.1016/j.gloenvcha.2013.12.012.

Goerlandt, F., Montewka, J., 2015. A framework for risk analysis of Maritime transportation systems: a case study for oil spill from tankers in a Ship–ship collision. Saf. Sci. 76, 42–66. https://doi.org/10.1016/j.ssci.2015.02.009.

Greenpeace, Naturog Ungdom, 2017. Media Briefing: The People vs. Arctic Oil. Climate Court Case Against the Norwegian Government for Opening New Fields in the Arctic. (Accessed 10 October 2017). http://www.greenpeace.org/norway/Global/norway/Hav/2017_ClimateLawsuit_Media%20Briefings/Media%20Briefing%20Lawsuit.pdf.

Gregory, R., Failing, L., Ohlson, D., Mcdaniels, T.L., 2006. Some pitfalls of an overemphasis on science in environmental risk management decisions. J. Risk Res. 9 (7), 717–735. https://doi.org/10.1080/13669870600799895.

Gulas, S., Downton, M., D'Souza, K., Hayden, K., Walker, T.R., 2017. Declining Arctic Ocean oil and gas developments: opportunities to improve governance and environmental pollution control. Mar. Policy 75, 53–61. https://doi.org/10.1016/j.marpol.2016.10.014.

Haapasaari, P., Mäntyniemi, S., Kuikka, S., 2012. Baltic herring fisheries management: stakeholder views to frame the problem. Ecol. Soc. 17 (3). https://doi.org/10.5751/ES-04907-170336.

Hauge, K.H., Blanchard, A., Andersen, G., Boland, R., Grøsvik, B.E., Howell, D., Meier, S., Olsen, E., Vikebø, F., 2014. Inadequate risk assessments – a study on worst-case scenarios related to petroleum exploitation in the Lofoten Area. Mar. Policy 44, 82–89. https://doi.org/10.1016/j.marpol.2013.07.008.

Helle, I., Ahtiainen, H., Luoma, E., Hänninen, M., Kuikka, S., 2015. A probabilistic approach for a cost-benefit analysis of oil spill management under uncertainty: a Bayesian network model for the Gulf of Finland. J. Environ. Manage. 158, 122–132. https://doi.org/10.1016/j.jenvman.2015.04.042.

Henly-Shepard, S., Gray, S.A., Cox, L.J., 2015. The use of participatory modeling to promote social learning and facilitate community disaster planning. Environ. Sci. Policy 45, 109–122. https://doi.org/10.1016/j.envsci.2014.10.004.

ICCP, 2018. Global warming of 1.5 °C: an IPCC special report on the impacts of global warming of 1.5°C above pre- industrial levels and related global greenhouse gas emission pathways. the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. IPPC 2018 (accessed 19 October 2018). http://www.ipcc.ch/report/sr15/.

The Barents Sea – ecosystem, resources, management. In: Jakobsen, T., Ozhigin, V. (Eds.), Half A Century of Russian-Norwegian Cooperation. Tapir Academic Press, Trondheim, Norway.

Janssen, M., Ostrom, E., 2006. Empirically based, agent-based models. Ecol. Soc. 11 (2). https://doi.org/10.5751/ES-01861-110237.

Jasanoff, S., 1995. Procedural choices in regulatory science. Technol. Soc. 17 (3), 279–293. https://doi.org/10.1016/0160-791X(95)00011-F.

Jasanoff, S., 1998. The political science of risk perception. reliability engineering & system safety. Risk Percep. Versus Risk Anal. 59 (1), 91–99. https://doi.org/10.1016/S0951-8320(97)00129-4.

Jasanoff, S., 2003. Technologies of humility: citizen participation in governing science. Minerva 41 (3), 223–244. https://doi.org/10.1023/A:1025557512320.

Jones, N.A., Ross, H., Lynam, T., Perez, P., Leitch, A., 2011. Mental models: an interdisciplinary synthesis of theory and methods. Ecol. Soc. 16 (1) pp. 46.

Klinke, A., Renn, O., 2012. Adaptive and integrative governance on risk and uncertainty. J. Risk Res. 15 (3), 273–292. https://doi.org/10.1080/13669877.2011.636838.

Knol, M., 2010a. Constructing knowledge gaps in Barents Sea management: how uncertainties become objects of risk. MAST 9 (1), 61–79.

Knol, M., 2010b. Scientific advice in integrated ocean management: the process towards the Barents Sea plan. Mar. Policy 34 (2), 252–260. https://doi.org/10.1016/j.marpol.2009.07.009.

Knol, M., Arbo, P., 2014. Oil spill response in the Arctic: Norwegian experiences and future perspectives. Mar. Policy 50 (Part A), 171–177. https://doi.org/10.1016/j.marpol.2014.06.003.

Kuikka, S., Varis, O., 1997. Uncertainties of climatic change impacts in Finnish watersheds: a Bayesian network analysis of expert knowledge. Boreal Environ. Res. 2 (1), 109–128.

Lecklin, T., Ryömä, R., Kuikka, S., 2011. A Bayesian network for analyzing biological acute and long-term impacts of an oil spill in the Gulf of Finland. Mar. Pollut. Bull. 62 (12), 2822–2835. https://doi.org/10.1016/j.marpolbul.2011.08.045.

Lehikoinen, A., Hänninen, M., Storgård, J., Luoma, E., Mäntyniemi, S., Kuikka, S., 2015. A Bayesian network for assessing the collision induced risk of an oil accident in the Gulf of Finland. Environ. Sci. Technol. 49 (9), 5301–5309. https://doi.org/10.1021/es501777g.

Lejano, R.P., Ingram, H., 2009. Collaborative networks and new ways of knowing. Environ. Sci. Policy 12 (6), 653–662. https://doi.org/10.1016/j.envsci.2008.09.005. Collaborative Governance and Adaptive Management: California's CALFED Water Program.

Mäkinen, J., Vanhatalo, J., 2018. Hierarchical Bayesian model reveals the distributional shifts of Arctic Marine mammals. Divers. Distrib. 24 (10), 1381–1394. https://doi.org/10.1111/ddi.12776.

Marchi, Bde., 2015. Risk Governance and the Integration of Different Types of Knowledge. In Risk Governance: The Articulation of Hazard, Politics and Ecology. Springer, Dordrecth.

McGlade, C., Ekins, P., 2014. Un-burnable oil: an examination of oil resource utilisation in a decarbonised energy system. Energy Policy 64, 102–112.

Montewka, J., Weckström, M., Kujala, P., 2013. A probabilistic model estimating oil spill clean-up costs – a case study for the Gulf of Finland. Mar. Pollut. Bull. 76 (1), 61–71. https://doi.org/10.1016/j.marpolbul.2013.09.031.

MPE (Ministry of Petroleum and Energy), 2011. Meld. St. 28 (2010 – 2011). Stortingsmelding. Regjeringen.no. June 24, 2011 (accessed 28 June 2018). https://www.regjeringen.no/no/dokumenter/meld-st-28-2010-2011/id649699/.

MPE (Ministry of Petroleum and Energy), 2013a. "Meld. St. 36 (2012–2013)." Stortingsmelding. Regjeringen.no. April 26, 2013. (accessed 26 June 2018). https://www.regjeringen.no/no/dokumenter/meld-st-36-20122013/id725083/.

MPE (Ministry of Petroleum and Energy), 2013b. "Meld. St. 41 (2012–2013)." Stortingsmelding. Regjeringen.no. June 7, 2013. (accessed 26 June 2018). https://www.regjeringen.no/no/dokumenter/meld-st-41-20122013/id729235/.

MPE (Ministry of Petroleum and Energy), 2017. "Høring - forslag om blokker til utlysning i 24. konsesjonsrunde." Horing. Regjeringen.no. March 13, 2017. (accessed 27 June 2018). https://www.regjeringen.no/no/dokumenter/horing—forslag-om-blokker-til-utlysning-i-24.-konsesjonsrunde/id2542893/.

Neil, M., Fenton, N., Nielsen, L., 2000. Building large-scale Bayesian networks. Knowl. Eng. Rev. 15 (3), 257–284. https://doi.org/10.1017/S0269888900003039.

Nevalainen, M., Helle, I., Vanhatalo, J., 2017. Preparing for the unprecedented — towards quantitative oil risk assessment in the Arctic Marine areas. Mar. Pollut. Bull. 114 (1), 90–101. https://doi.org/10.1016/j.marpolbul.2016.08.064.

Nevalainen, M., Helle, I., Vanhatalo, J., 2018. Estimating the acute impacts of Arctic Marine oil spills using expert elicitation. Mar. Pollut. Bull. 131, 782–792. https://doi.org/10.1016/j.marpolbul.2018.04.076.

NMCE (Norwegian Ministry of the Climate and Environment), 2015. Update of the Integrated Management Plan for the Barents Sea – Lofoten Area Including an Update of the Delimitation of the Marginal Ice Zone. Meld. St. 20 (2014-2015) Report to the Storting (White Paper). (accessed 21 March 2018). https://www.regjeringen.no/contentassets/d6743df219c74ea198e50d9778720e5a/en-gb/pdfs/stm201420150020000engpdfs.pdf.

NME (Norwegian Ministry of Environment), 2001. Protecting the Riches of the Seas. Report No. 12 to the Storting (2001–2002). (accessed 11 November 2018). https://www.regjeringen.no/contentassets/f4f553f05ca1417eaccbdca6e4e6c4be/en-gb/pdfs/stm200120020012000en_pdfs.pdf.

NME (Norwegian Ministry of Environment), 2006. Integrated Management of the Marine Environment of the Barents Sea and the Sea Areas off the Lofoten Islands. Report No. 8 to the Storting (2005–2006) (accessed 11 November 2018).

NME (Norwegian Ministry of Environment), 2011. First Update of the Integrated Management Plan for the Marine Environment of the Barents Sea – Lofoten Area. Meld. St. 10 (2010–2011) Report to the Storting (White Paper). (accessed 23 March 2018).

Norwegian Petroleum, 2018. The Petroleum Act and the Licensing System.

Norwegianpetroleum.No. 2018. (accessed 19 October 2018. https://www.norskpetroleum.no/en/framework/the-petroleum-act-and-the-licensing-system/.
NPD (Norwegian Petroleum Directorate), 2017a. Doubling the Resource Estimate for the Barents Sea. April 25, 2017 (accessed 21 August 2018). http://www.npd.no/en/news/News/2017/Doubling-the-resource-estimate-for-the-Barents-Sea/.
NPD (Norwegian Petroleum Directorate), 2018. 12 Production Licences Offered to 11 Companies in the 24th Licensing Round - Norwegian Petroleum Directorate. June 18, 2018 (accessed 19 June 2018). http://www.npd.no/en/Licensing-rounds/Licensing-rounds/24th-Licencing-round/Offers-for-ownership-interests-in-the-24th-licensing-round/.
NPD (Norwegian Petroleum Directorate), 2017b. 24th Licensing Round - Announcement. June 22, 2017. (accessed 21 August 2018). http://www.npd.no/en/Licensing-rounds/Licensing-rounds/24th-Licencing-round/Announcement/.
NPD, NMPE (Norwegian Petroleum Directorate, Norwegian Ministry of Petroleum and Energy), 2018. Norwegianpetroleum.No - Facts About Norwegian Petroleum Activites. Norwegianpetroleum. No. 2018. (accessed 14 June 2018). https://www.norskpetroleum.no/en/.
Nuka Research and Planning Group, LLC, Pearson Consulting, LLC, 2010. Oil Spill Prevention and Response in the U.S. Arctic Ocean: Unexamined Risks, Unaccetable Consequences. U.S Arctic Program, Pew Environment Group. http://www.pew-trusts.org/~/media/legacy/uploadedfiles/peg/publications/report/oil20spill20pre-ventionpdf.pdf (accessed 15 May 2017).
Nutley, S., Walter, I., Davies, H., 2007. Using Evidence: How Research Can Inform Public Services. Policy Press, Bristol.
Nyberg, J.B., Marcot, B.G., Sulyma, R., 2006. Using Bayesian belief networks in adaptive management. Can. J. For. Res. 36 (12), 3104–3116.
Olsen, E., Holen, S., Hoel, A.H., Buhl-Mortensen, L., Røttingen, I., 2016. How integrated ocean governance in the Barents Sea was created by a Drive for increased oil production. Mar. Policy 71, 293–300. https://doi.org/10.1016/j.marpol.2015.12.005.
Özesmi, U., Özesmi, S.L., 2004. Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecol. Modell. 176 (1), 43–164. https://doi.org/10.1016/j.ecolmodel.2003.10.027.
Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., Taillieu, T., 2007. Social learning and water resources management. Ecol. Soc. 12 (2) pp. Art. 5-Art. 5.
Petrick, S., Riemann-Campe, K., Hoog, S., Growitsch, C., Schwind, H., Gerdes, R., Rehdanz, K., 2017. Climate change, future Arctic Sea ice, and the competitiveness of European Arctic offshore oil and gas production on world markets. Ambio 46 (3), 410–422. https://doi.org/10.1007/s13280-017-0957-z.
Petts, J., 2004. Barriers to participation and deliberation in risk decisions: evidence from waste management. J. Risk Res. 7 (2), 115–133. https://doi.org/10.1080/1366987042000158695.
Renn, O., 2008. Risk governance. Coping With Uncertainty in a Complex World. Earthscan, London.
Renn, O., Klinke, A., van Asselt, M., 2011. Coping with complexity, uncertainty and ambiguity in risk governance: a synthesis. AMBIO 40 (2), 231–246. https://doi.org/10.1007/s13280-010-0134-0.
Robards, M.D., Huntington, H.P., Druckenmiller, M., Lefevre, J., Moses, S.K., Stevenson, Z., Watson, A., Williams, M., 2018. Understanding and adapting to observed changes in the Alaskan Arctic: actionable knowledge Co-production with Alaska native communities. Deep Sea Research Part II: Topical Studies in Oceanography. https://doi.org/10.1016/j.dsr2.2018.02.008. February.
Rowe, G., Frewer, L.J., 2005. A typology of public engagement mechanisms. Sci. Technol. Human Values 30 (2), 251–290. https://doi.org/10.1177/0162243904271724.
Sander, G., 2018. Against all odds? Implementing a policy for ecosystem-based management of the Barents Sea. Ocean Coast. Manage. 157, 111–123. https://doi.org/10.1016/j.ocecoaman.2018.01.020.
Sarewitz, D., Pielke, R.A., 2007. The neglected heart of science policy: reconciling supply of and demand for science. Environ. Sci. Policy 10 (1), 5–16. https://doi.org/10.1016/j.envsci.2006.10.001. Reconciling the Supply of and Demand for Science, with a Focus on Carbon Cycle Research.
Slovic, P., 2001. The risk game. J. Hazard. Mater. 86 (1), 17–24. https://doi.org/10.1016/S0304-3894(01)00248-5. Risk and Governance.
Spaulding, M.L., 2017. State of the art review and future directions in oil spill modeling. Mar. Pollut. Bull. 115 (1), 7–19. https://doi.org/10.1016/j.marpolbul.2017.01.001.
Staalesen, A., 2018. Oil-Hungry Industry Gets Big Arctic Opening Near Protected Svalbard Waters. The Independent Barents Observer. June 18, 2018 (accessed 19 June 2018). https://thebarentsobserver.com/en/industry-and-energy/2018/06/oil-hungry-industry-gets-big-arctic-opening-near-protected-svalbard.
Stewart, G.B., Mengersen, K., Meader, N., 2014. Potential uses of Bayesian networks as tools for synthesis of systematic reviews of complex interventions. Res. Synth. Methods 5 (1), 1–12. https://doi.org/10.1002/jrsm.1087.
Stortinget, 2015. Oppdatering av forvaltningsplanen for Barentshavet og havområdene utenfor Lofoten med oppdatert beregning av iskanten. Sak. Stortinget. April 28, 2015. (accessed 15 March 2019). https://www.stortinget.no/no/Saker-og-publikasjoner/Saker/Sak/?p=61808.
Sydnes, M., Sydnes, A.K., 2011. Oil spill emergency response in Norway: coordinating interorganizational complexity. Polar Geogr. 34 (4), 299–329. https://doi.org/10.1080/1088937X.2011.620721.
UNIIN-BARENTS, 2018. Stakeholder Monitoring Report: What Kind of Information Is Needed for Planning and Implementation of the Development Projects in the Barents Region? UNIIN-BARENTS - "University-Industry Interlink Towards Value Creation in the Barents Region", Supported by The Norwegian Barents Secretariat. (accessed 24 October 2018). http://www.intercenterarco.com/files/attachments/0000/0569/58e88ae748aed08dc46c67b8a8658fc78ccb3b08.pdf.
Uusitalo, L., 2007. Advantages and challenges of Bayesian networks in environmental modelling. Ecol. Modell. 203 (3–4), 312–318.
Van Der Sluijs, J.P., Craye, M., Funtowicz, S., Kloprogge, P., Ravetz, J., Risbey, J., 2005. Combining quantitative and qualitative measures of uncertainty in model-based environmental assessment: the NUSAP system. Risk Anal. 25 (2), 481–492. https://doi.org/10.1111/j.1539-6924.2005.00604.x.
Van Vliet, M., Kok, K., Veldkamp, T., 2010. Linking stakeholders and modellers in scenario studies: the use of fuzzy cognitive maps as a communication and learning tool. Futures 42 (1), 1–14. https://doi.org/10.1016/j.futures.2009.08.005.
Voinov, A., Bousquet, F., 2010. Modelling with stakeholders. Environ. Modell. Software 25 (11), 1268–1281. https://doi.org/10.1016/j.envsoft.2010.03.007.
Wilkinson, J., Beegle-Krause, C.J., Evers, K., Hughes, N., Lewis, A., Reed, M., Wadhams, P., 2017. Oil spill response capabilities and technologies for ice-covered arctic Marine waters: a review of recent developments and established practices. Ambio 46 (3), 423–441. https://doi.org/10.1007/s13280-017-0958-y.
Wynne, B., 2005. Reflexing complexity: Post-genomic knowledge and reductionist returns in public science. Theory Cult. Soc. 22 (5), 67–94. https://doi.org/10.1177/0263276405057192.
Wynne, B., 2011. Lab work goes social, and vice versa: strategising public engagement processes. Sci. Eng. Ethics 17 (4), 791–800. https://doi.org/10.1007/s11948-011-9316-9.
Yearley, S., 2000. Making systematic sense of public discontents with expert knowledge: two analytical approaches and a case study. Public Understanding Sci. 9 (2), 105–122. https://doi.org/10.1088/0963-6625/9/2/302.